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HEADLINE: UptimeOne's E-Commerce Infrastructure Software Renovates FurnitureOnline.com into an Interactive Site

DATELINE: SAN JOSE, Calif., Dec. 13, 1999

BODY:

Holiday Shoppers Can Now Obtain Instant Updates on Furniture Inventory Offerings and Pricing, and Shop Safely with Signio's Payment Processing Solution

UptimeOne, Inc., a leading provider of e-business software and solutions for dot.com and mid-sized companies, has implemented interactive purchasing capabilities for FurnitureOnline.com.

Using the renovated site, shoppers can now instantly receive availability and pricing information on any furniture item.

Before UptimeOne's e-businessOne(TM) suite of modular e-commerce infrastructure software, FurnitureOnline's shoppers submitted an online order form and waited for a response from a customer service representative. This process meant that a customer had to wait for the salesperson to research the product and return the call.

Today, UptimeOne's technology empowers FurnitureOnline.com to save its customers time and energy by offering real-time ordering capabilities through an up-to-date online catalog of furniture choices, 24 hours per day, 7 days per week.

"During this holiday season, it is extremely important for us to broaden our Web site's offerings," said Rich Peterson, chairman and CEO of FurnitureOnline.com.

"Implementing UptimeOne's e-business technology in under 60 days has enabled us to quickly offer our customers a time-saving proposition that ensures they will have access to the latest furniture products and pricing. In turn, our sales force can offer value-added customer service to ensure timely purchase and delivery."

UptimeOne's e-businessOne suite is a scalable solution that allows for quick implementation and easy customization with existing IT infrastructure. e-businessOne is extensible and responsive to emerging customer needs, changing market demands, and steep increases in the number of users.

The implementation of e-businessOne on FurnitureOnline.com adds flexible search functionality that enables customers to intelligently search for products based on price, manufacturer, and type of finish.

Another value-added service available on the site is one-to-one personalization through which repeat shoppers are provided with a record of their purchase history and preferences, which streamlines future

shopping transactions.

Along with UptimeOne's e-businessOne, Signio's Payflow Pro solution was implemented in order to provide real-time secure online credit card authorization for FurnitureOnline.com's customers.

Payflow Pro also allows FurnitureOnline.com to accept unlimited debit and purchase card transactions, Internet check and ACH (Automated Clearing House) transactions, all with an average per-transaction time of under three seconds.

"Unlike other HTTP-based payment solutions, Signio's Payflow Pro ensures safe shopping on FurnitureOnline.com by maintaining the payment transaction during the entire process," said Philippe Courtot, CEO and chairman of Signio Inc.

"Our product works seamlessly with UptimeOne's e-businessOne to process a purchaser's data and rapidly respond to a customer's payment request, resulting in an extremely efficient transaction for FurnitureOnline.com and its customers."

UptimeOne also implemented an intranet for FurnitureOnline.com's sales team. With secure login and password access, FurnitureOnline.com salespersons have the ability to customize a sale by offering quantity discounts, customizing terms of payment, etc.

"Our e-businessOne solution was designed to help companies like FurnitureOnline.com focus on what they do best -- generating sales and providing customer care," says Naresh Batra, chief executive officer at UptimeOne. "With a sound, scalable infrastructure that's quick to implement, our clients are able to obtain a wealth of opportunities in today's exploding e-commerce market."

About UptimeOne

UptimeOne, Inc. is a leading provider of e-commerce and e-business infrastructure software and solutions to dot.com and mid-sized companies. The e-businessOne(TM) suite of modular software provides a highly scalable, flexible, and feature-rich solution that allows companies to do business on the Web quickly and at low cost.

The software ranges from a basic order entry and catalog system to a complete online extranet that allows customers and partners to access their account information securely. The fast time-to-implementation, integration, and scalability of the UptimeOne e-businessOne solution gives customers a key competitive advantage. UptimeOne is headquartered in San Jose. For more information, visit the UptimeOne Web site at http://www.uptimeone.com.

About FurnitureOnline.com

FurnitureOnline.com has been in the business of selling quality furniture over the Internet since March of 1996, making it one of the pioneers of Internet furniture retailing. The founders of FurnitureOnline.com are career furniture executives with over 45 years of combined industry experience.

FurnitureOnline.com offers several categories of furniture, but has quickly become the dominant player in the Small Office Home Office (SOHO) and Ready To Assemble (RTA) arena that caters to customers seeking office furniture. FurnitureOnline.com has been so successful in this segment that the company recently acquired OfficeFurniture.com.

Today, FurnitureOnline.com's customers range from telecommuters to corporations, as well as government agencies and universities. In addition to office furniture, FurnitureOnline.com carries a wide selection of home furnishings that complement any environment.

About Signio

Signio Inc. (formerly known as PaymentNet) simplifies e-commerce by providing payment connectivity over the Internet between buyers, sellers, and financial networks. Signio brings affordability and ease of use to the process of buying and selling online.

With its flat fee monthly pricing model and a growing menu of services, the Signio Payflow Service delivers a wide range of payment connectivity including all major credit card, debit card, electronic check, purchase card, and Automated Clearing House (ACH) transactions. Its robust, scalable and open architecture is designed to support business-to-consumer (B2C) and business-to-business (B2B) payment applications.

Signio has a growing list of impressive customers and partners, with notable merchants such as CBS Sportsline, CNET Store.com, wine.com, WebMD, women.com and e-commerce solution providers such as Commerce One, Intuit, Trading Dynamics, Fairmarket and Just in Time Solutions. Signio is headquartered in Redwood Shores, Calif.

For more information about Signio, visit http://www.signio.com.

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I. INTRODUCTION

Recently there has been tremendous progress in information technology. Fast technological progress in the software and hardware of PCs makes the purchase decision difficult. Business users and home users of PCs ask questions about when it is the right time to buy and how much they should pay for the new technology. Considering the fact that information technology is crucial in the determination of the productivity of the economy for the future, these questions are very important ones. These cannot be answered from the consumer's point of view in isolation from the strategic response of the producer since the consumer's decision is yet another strategic response to the decision of the producer.

This paper addresses the issue of the equilibrium behavior of the producer and the consumer for a product which is subject to fast technological progress. We approach the issue in the framework of a durable goods monopoly under technological innovation. Once the consumers buy a PC or software, they use it for a while. Much software and hardware are produced by a few big firms with substantial market power.

As is well known since Coase [1972], a durable goods monopolist is subject to a time consistency problem even in the absence of the possibility of technological progress. The time consistency issue arises because the durable goods monopolist attempts to price discriminate over time between consumers with different valuations. Bulow [1982] and Stokey [1981] provided a rigorous analysis of the problem and established that the monopolist may have to give up monopoly power at the equilibrium.

In the context of the original durable goods monopoly, Coase [1972] and Bulow [1986] suggested that the monopolist may introduce planned obsolescence to avoid the difficulty of price discrimination over time. Reduced durability strengthens the monopolist's market power because with reduced durability the monopolist can behave like a non-durable goods monopolist.

The present paper departs from this literature and asks whether the monopolist becomes better off by introducing economic obsolescence. Technological innovation reduces the economic life of durable goods; when a better technology is available, the old technology becomes less useful compared with the state-of-the-art technology even if its physical productivity remains the same. The old technology becomes economically obsolete.

We approach the choice of economic obsolescence from the viewpoint of price discrimination. When a new durable good is produced after the old generation of the durable good is sold, the monopolist has to price discriminate not only between consumers with different valuations but also between consumers with different purchase histories. The new generation of the durable good has to be offered to the existing user at a discount due to the fact that existing users have the old durable good which is still functioning. This observation suggests that users may want to by-pass the old product and buy the new product at the discount meant for the existing users. Since this strategy contradicts the hypothesis that existing users have purchased the old product, it cannot constitute the equilibrium.

The consumers' expectation of the availability of a higher quality product in the subsequent period may discourage the purchase of the old product in the first period. We show that the monopolist may not be successful in price discriminating between consumers with different purchase histories and valuations using standard tools. In order to avoid this incentive problem, the monopolist may need a device to price discriminate between consumers according to their past purchase history. We establish that the additional strategy of an upgrade policy helps the monopolist in this respect, although it may be imperfect. The main result completely characterizes the equilibrium price path of the durable good when technological innovation provides a better durable good in the future. We also show that depending on the performance of various price discrimination schemes, the monopolist may delay technological progress by investing less in R&D than is socially optimal.

Our result makes it clear how the extent of technological innovation and the relative sizes of the high-end market and the low-end market determine the equilibrium price path and consequently how the investment decision on technological innovation would be made by the monopolist. In particular a technological innovation potentially brings about a reallocation of surplus between the agents in such a way that a certain group of consumers are offered a bigger consumer surplus. If the innovation cost is big enough to cancel out the additional profit the monopolist makes with the new product, the monopolist optimally chooses not to invest in the innovation even though the social surplus, which includes the additional consumer surplus as well as the monopolist's profit, is bigger than the cost of innovation.

The intuition can be explained by the interaction of two price discrimination schemes. The first one is the standard price discrimination which induces consumers with different valuations to self-select. In the context of durable goods monopoly, the monopolist achieves this by reducing price over time. The second one is unique to the present setting where the consumers with the same valuation of the durable good may have different purchase histories. As observed above, consumers who have purchased the old durable good gain only the incremental utility from the purchase of the new durable good. To induce existing consumers to purchase the new product, the monopolist has to offer a discount to these consumers. Hence consumers with different valuations may have a similar willingness to pay for the new product in the second period after taking account of the fact that consumers with a high valuation already have the old product. It is this link between the two price discrimination schemes that produces a variety of cases. If the incremental utility of the new product for the existing consumers is high, the monopolist chooses to forego the low-end market in that the consumers with a low valuation are supplied only the old product in the second period. If the low-end market is big and their valuation from the new product is reasonably high, consumers in the high-end market may be asked to pay only the utility of the consumers with a low valuation. It follows that a different reallocation of surplus may result at the equilibrium depending on the valuations of different consumers and the size of each consumer group.

Bulow [1986], Bond and Samuelson [1986], Waldman [1993] and Choi [1994] have investigated the effect of the introduction of planned obsolescence on the equilibrium in the durable goods monopoly. They broadly agreed that the monopolist prefers to shorten the physical life of the durable goods. However they

largely neglected the possibility that durability can be reduced not only in a physical sense but also in an economic sense.

Given the important implication of technological progress for the productivity of the economy, systematic analyses of the problem of economic obsolescence are rare. Fishman, Gandal, and Shy [1993] first observed the difficulty caused by the fact that existing consumers are willing to pay only the incremental utility for the new technology. They focused on the benign aspect of the shorter economic life of durable goods in promoting the development of a better generation. More recently, Fudenberg and Tirole [1996] provided a thorough analysis of the price discrimination scheme in a more general setting than ours. However, they fall short of analyzing the choice of economic obsolescence as a consequence of the strategic interaction between the monopolist and consumers.

Levinthal and Puroit [1989] and van Ackere and Reyniers [1995] address the similar issue of buy-backs and trade-ins with which the monopolist offers a lower price for those who purchased the durable good from him in the past. Their analyses emphasize the issue of an optimal marketing strategy instead of questions relating to economic obsolescence.

The interpretation of upgrade policy as a price discrimination device is related to the literature on the secondhand market such as Swan [1972], Rust [1986] and Anderson and Ginsburgh [1994]. They do not address the issue of time inconsistency and also do not take account of the possibility that the new product has a higher utility to previous buyers. They establish that without endogenous scrapping by consumers, the equilibrium without secondhand markets coincides with the equilibrium with secondhand market so that the existence of the secondhand market itself does not give the monopolist an incentive to distort the durability of the product.

Arrow [1962] and Reinganum [1983] suggested that an underinvestment in innovation may follow from the fear of cannibalizing the stream of rents from the existing technology. In our context the underinvestment in the innovation in the durable goods relies on more than the cannibalization of the future rent stream. In particular, technological innovation in durable goods cannibalizes not only the stream of future rents but also the stream before the innovation because the availability of a better product in the future makes consumers less willing to buy the old product before the innovation.

In the next section we introduce a two period durable goods monopoly model without innovation costs and formulate it into a game between the monopolist and two types of consumers. In Section III, we analyze the monopoly market equilibrium under various conditions on the parameters and market institutions. based on the analysis of the durable goods monopoly under a given technological innovation in Section III, Section IV further investigates the R&D investment choice in the presence of innovation costs. Section V concludes the paper.

II. MODEL

We first consider a simple two period durable goods monopoly model without considering the investment decision into technological innovation. The model serves as the basis for the analysis of the choice of economic obsolescence in Section IV where the monopolist decides whether to invest in innovation.

A monopolist produces and sells durable goods over two periods. The durable good produced in the first period lasts two periods. In the second period the monopolist produces a different product that gives a higher value to the consumers due to technological innovation. The marginal costs of producing both products are constant and further assumed to be zero with little loss of generality because prices are interpreted as being net of constant marginal cost.

The monopolist sells the durable good to two groups of consumers with different valuations of the durable good and a consumer has a type, [Theta] [element of] [H,L], known only to the consumer. There is a continuum of consumers of each type where the measure of type H is normalized to 1 and the measure of type L is [Mu], [Mu] [greater than or equal to] 0. The durable good produced in We assume that the period t gives the consumer of type [Theta] a utility of [Mathematical Expression Omitted]. We assume that the product has a higher value to the consumer of type H than [Mathematical Expression Omitted]. The good produced in period 2 is a better product for both types of consumers due to technological innovation, that is, [Mathematical Expression Omitted], for [Theta] = H, L. Each consumer uses at most one unit of the durable good in each period. A consumer who purchases in the first period may continue to use the good in the second period, thus obtaining the same utility as previously or he may choose to buy a new product. This feature captures the distinct aspect of the durable goods monopoly under technological innovation. That is, when technological innovation offers a better product at a lower price, consumers may move to the new product even if the old one is not obsolete in a physical sense.

To keep the setting as simple as possible, we assume that if a new product is purchased in the second period, the old product is scrapped. In other words, we assume that there is no secondhand market for the old product in the second period. We also assume no discounting for the monopolist and consumers. Finally we assume that the consumer purchases the product if he is indifferent between buying and not buying.

The monopolist maximizes profits by setting the optimal prices in both periods for each product. Since there is a continuum of each type, consumers act as price takers. We allow an additional strategy to the monopolist - the upgrade policy which helps to price discriminate between repeat buyers and new buyers.(1) In particular, we assume that in the second period, the monopolist may price discriminate between consumers according to whether they have purchased in the first period or not. If the consumer can provide a receipt of first period purchase, he can purchase the new product at a different price from a new purchaser. However, the consumer could choose to conceal the previous purchase if it benefits him.

In the following we compute the consumer surplus and the monopolist's profit for various purchasing strategies given a price sequence ([p.sub.1], [Mathematical Expression Omitted], [Mathematical Expression Omitted], [Mathematical Expression Omitted]) where [Mathematical Expression Omitted], [Mathematical Expression Omitted], [Mathematical Expression Omitted], and [Mathematical Expression Omitted] are the first period price, the second period price of the old product, the upgrade price of the new product and the second period new purchase price of the new product, respectively. If a consumer of type 0 purchases in the first period and continues to use the old product in the second period, he gets a consumer surplus of [Mathematical Expression Omitted]. If he purchases the new product in the second period, his surplus is [Mathematical Expression Omitted], while it is [Mathematical Expression Omitted] if he purchases the old product in the second period. Finally if he purchases both products, his total surplus is computed as [Mathematical Expression Omitted]. It is important to note that if a consumer purchases in both periods, his additional utility from the new product at the time of purchase in the second period is [Mathematical Expression Omitted] since he can continue to use the old product and so enjoy utility [Mathematical Expression Omitted] without incurring additional costs. Hence the monopolist cannot charge a second period price higher than [Mathematical Expression Omitted] to the consumer who purchases in both periods. The corresponding monopolist's total profit is computed as [Mathematical Expression Omitted] where [q.sub.1], [Mathematical Expression Omitted], [Mathematical Expression Omitted] and [Mathematical Expression Omitted] are first period sales, second-period old product sales, upgrade sales and second-period new sales of the new product, respectively.

We use subgame perfection as our equilibrium criterion. We consider only equilibria in pure strategies that

are symmetric in the sense that consumers of the same type play the same pure strategy along the equilibrium path.

We make the following assumptions to focus on interesting cases in the spirit of the classical durable goods monopoly problem.

Assumption 1 [Mathematical Expression Omitted].

Assumption 2 [Mathematical Expression Omitted].

Assumption 1 says that the monopolist would make higher profits by selling only to type H consumers in period 1 if there is no innovation. Assumption 2 implies that if both types have purchased in the first period, the monopolist makes a higher profit by selling only to the type H consumers than to both consumer groups in the second period.(2) Together they imply that monopoly matters since the monopolist finds it optimal to restrict the output.

III. ANALYSIS

Some preliminary observations help in understanding the analysis. Firstly, if there is no technological innovation in the second period, our model is basically identical to Bulow [1982]. Without technological innovation, consumers of type H will purchase the product in the first period and consumers of type L will purchase the good in the second period. The incentive compatibility constraint of a consumer of type H requires that he is at least indifferent between purchasing in the first period and waiting until the second period; [Mathematical Expression Omitted]. The monopolist's profit maximization problem, given the incentive constraint of consumer L determines the second period price as [Mathematical Expression Omitted]. Thus the corresponding equilibrium price in the first period is [Mathematical Expression Omitted] and the profit of the monopolist is [Mathematical Expression Omitted]. From this play, type H consumers get a surplus of [Mathematical Expression Omitted] and type L consumers get zero surplus.

Next, the monopolist's solution to the rental problem is obtained by solving the static profit maximization problem in each period. Under Assumptions 1 and 2, it is straightforward to show that the monopolist only rents to type H consumers, in each period thus making a total profit of [Mathematical Expression Omitted], while both types of consumers get no surplus. This implies that the monopoly results in an inefficiency in the rental case since Pareto optimality dictates that he rent to both types of consumers.

The two above cases serve as benchmarks for our main results. We refer to the first case as the classical sales case and to the second case as the rental case, respectively. From now on, we focus our attention on the sales problem only.(3)

III(i). Upgrade Policy

If technological innovation is expected in the future, consumers are willing to pay only an amount corresponding to the value of the current durable good up to the time when a new product arrives. Nevertheless, consumers can use the old product as the reference point in the future when they purchase a new product since the old product still has a remaining physical life and thus a rental value. Consequently, the highest second period price the monopolist can charge to consumers who already own the old product is the utility difference between the new product and the old product. However, if the second period price is set equal to the utility difference, an individual consumer does better by not purchasing the old product and getting the consumer surplus caused by the discount on the new product in the second period. This simple observation explains the role of an upgrade policy.

Lemma 1

Assume there is no low valuation consumer, i.e., [Mu] = 0, and the monopolist cannot implement an upgrade policy. Then there is a subgame perfect equilibrium of the game F in which the monopolist charges [Mathematical Expression Omitted] and [Mathematical Expression Omitted] and consumers of type H purchase in both periods.

Proof

Given that a consumer of type H has purchased in the first period, the second period price of the new product cannot exceed [Mathematical Expression Omitted] otherwise the consumer will continue using the old product with utility of with no additional cost. Thus, the consumer's incentive constraint satisfies [Mathematical Expression Omitted]. It is immediate to show that for any [p.sub.2], [p.sub.1] cannot exceed [Mathematical Expression Omitted] and the lemma follows.

Lemma 1 indicates that consumers buy both products only for the total payment of [Mathematical Expression Omitted]. This highly stylized result underscores the additional difficulty the monopolist faces because it arises in a setting in which the monopolist sells only to one type of consumers and thus there appears to be no need for price discrimination.

If there were no innovation, the monopolist could sell his product for [Mathematical Expression Omitted] in the first period and [Mathematical Expression Omitted] in the second period. Consumers gain no extra utility by waiting until the second period. In contrast, if innovation takes place the monopolist has to consider old customers when selling a new product in the second period. Since the repeat customers already possess old products, they can use that as a threat point in bargaining. Without the upgrade policy the monopolist cannot use the old product as the future threat point; an individual consumer can wait until the second period when the price of the new product decreases to [Mathematical Expression Omitted] in order to attract repeat buyers.

If the monopolist can implement the upgrade policy which enables him to price discriminate among consumers based on their **purchase history,** he can avoid this difficulty when there is only one type of consumer. Under the upgrade policy, an individual consumer cannot gain by not purchasing the old product since the new product can be purchased at the discount only with verification of the purchase history of the old product.

It is easy to see that the equilibrium in the game as considered in Lemma 1 is not unique. For instance it is possible that the monopolist sells only in the second period or implements a mixed strategy. However, our main point remains in that all these alternative equilibria yield less profit than the one available from an upgrade policy and thus underscore the important role of an upgrade policy. Moreover, any alternative equilibrium is characterized by delayed purchase where the delay implies an inefficiency since consumers cannot benefit from the consumption of the durable good in the first period. In contrast the upgrade policy enables the monopolist to price discriminate consumers without an inefficient delay in purchase.

However, an interesting interaction takes place if the monopolist has to sell to more than one type of consumer. Notice that the upgrade price has to be lower than the new purchase price. This restriction could be relevant if type L consumers have a low valuation of the new product. Suppose that only type H consumers purchase the old product in the first period To induce type L consumers to purchase the new product, the new purchase price in the second period may have to be set lower than the upgrade price. If the parameters satisfy the condition that [Mathematical Expression Omitted], the monopolist cannot

implement the upgrade policy in its simple form to induce type H consumers to purchase the new product at the upgrade price since they can buy it cheaper by not revealing their purchase history.

III(ii). Equilibrium

We are now prepared to solve for the equilibrium of the game [Gamma]. Proposition 1 provides a complete characterization of the subgame perfect equilibrium under a variety of conditions on the parameters.

Proposition 1

The subgame perfect equilibrium of the game [Gamma] is characterized as follows: Consumers of type H always purchase in both periods, and consumers of type L always purchase in the second period.

1. If [Mathematical Expression Omitted], the monopolist sets [Mathematical Expression Omitted], [Mathematical Expression Omitted], [Mathematical Expression Omitted] and the old product is shelved in the second period. Consumers of type H purchase the new product at the upgrade price in the second period and consumers of type L purchase the new product at the new purchase price in the second period.

2. If [Mathematical Expression Omitted], the monopolist sets [Mathematical Expression Omitted], [Mathematical Expression Omitted] and the old product is shelved in the second period. Consumers of type H and type L purchase the new product at the same price in the second period.

3. If [Mathematical Expression Omitted], the monopolist sets [Mathematical Expression Omitted], [Mathematical Expression Omitted], [Mathematical Expression Omitted], [Mathematical Expression Omitted] and the old product is offered for sale in the second period. Consumers of type H purchase the new product at the upgrade price in the second period and consumers of type L purchase the old product in the second period.

Proof

See Appendix.

The characterization of the subgame perfect equilibrium in Proposition 1 can be explained in terms of the interaction of two price discrimination schemes. Lemma 1 showed the role of the upgrade policy in price discriminating between consumers of the same type but different purchase histories. In addition, the monopolist has to implement price discrimination to induce consumers of different types to self-select. We call the first kind of price discrimination the intra-type one and the second kind of price discrimination the inter-type one.

The intra-type price discrimination is constrained by the reservation price effect, namely the fact that consumers who have purchased the old product would not pay their full utility for the new product. It follows that the new purchase price of the new product cannot be set lower than the upgrade price. Otherwise consumers with a previous purchase history would conceal it and buy as if they were new consumers. In particular if type L consumers have a low utility from the new product or if the incremental utility of the new product to type H consumers is high, the monopolist cannot achieve the intra-type price discrimination together with the inter-type one through the upgrade policy. In this circumstance, the monopolist can use the old product to price discriminate type L consumers in the second period. However, the implementation of this additional strategy is constrained by the ratchet effect. The monopolist can supply the old product at a cheap price in the second period since type H consumers have already self-selected in the first period. If the cheap price of the old product in the second period is anticipated,

however, type H consumers would not purchase the old product in the first period to begin with. Therefore the monopolist should allow enough surplus to type H consumers in the first period so that they are willing to buy despite the ratchet effect.

The condition for Case 1 implies that type H consumers can be separated from type L consumers through the upgrade policy. The upgrade price is set at [Mathematical Expression Omitted] which is below the new purchase price of the new product, [Mathematical Expression Omitted]. Therefore consumers of type H purchase the new product at the upgrade price in the second period and consumers of type L purchase the new product at the new purchase price in the second period. If this condition does not hold, the monopolist cannot induce both types to self-select with the upgrade policy. Instead the monopolist can offer a pooling price for both types or offer the old product to type L while type H consumers are offered the new product at the upgrade price of [Mathematical Expression Omitted]. If the monopolist chooses to offer both products in the second period, he has to maintain the upgrade policy to prevent type H consumers from taking advantage of the upgrade policy without purchasing the old product in the first period. The choice between the pooling price strategy and the product line strategy depends on which policy yields a higher profit in the second period. If the profit from the pooling price, [Mathematical Expression Omitted], exceeds the profit from product line, [Mathematical Expression Omitted], then the monopolist chooses the pooling price strategy as in Case 2, while if the latter exceeds the former, he chooses the product line as in Case 3. The profit from each strategy in turn depends on the relative market size as well as the incremental utility of the new product for both types. With the valuations of both products for both types fixed, the pooling strategy yields a bigger profit if the low-end market is big. If the incremental utility of the new product for type L consumers is small, the pooling strategy requires a huge lower-end market to be optimal.

The result accords well with some recent examples in the PC industry. Much application software is sold at an upgrade price to existing users while new users have to pay a substantially higher new purchase price as in Case 1. New generations of software usually have additional functions as well as fixes of problems in the previous versions. Since they do not offer functions so new that old versions could not continue to be used, existing users would not get a big incremental utility from the new versions. In contrast new users gain the total utility of the software which could be substantial and thus they are willing to pay the high price. Therefore the monopolist can price discriminate in selling the same product to both groups.

On the other hand, high-end PCs are sold to mainly existing business users at a high price while old generation PCs are sold to new home buyers at a low price. It is frequently documented that the price of high-end PCs is not in the range paid by consumers of electrical goods while it is well within the range for business users since new generation PCs offer not only faster speed but also a variety of additional functions which cannot be performed on old generation PCs. In contrast, home users may not obtain a big incremental utility from the new generation PCs since most basic functions are provided by the old generation PCs. Case 3 of Proposition 1 predicts that in this circumstance the monopolist would implement price discrimination by offering lines of products.

The equilibrium indicates that the monopolist always sells one or the other product to type L consumers in the second period. Since the price that type L consumers pay for any product is lower than the utility of the same product to type H consumers, the latter group of consumers must be allowed the surplus which is available from imitating the former group. This implies that the monopolist has to leave some consumer surplus to some consumers. Thus the monopolist may end up with less market power when the durable good becomes less durable in an economic sense, in contrast to the case of Bulow [1986] in which planned obsolescence would give the monopolist bigger market power. Indeed the next section shows that the choice of economic obsolescence hinges crucially on this observation.

IV. CHOICE OF ECONOMIC OBSOLESCENCE

The analysis of the monopoly market equilibrium given innovation in the previous section forms the basis for our investigation in to the choice of economic obsolescence when there is a positive innovation cost. In particular, we want to examine whether the monopolist would invest too much (too little) in the technological innovation, representing too much (too little) economic obsolescence, when the cost of the investment is entirely borne by himself.

To simplify the analysis, we adopt the simplest form of innovation cost; at the beginning of the whole game the monopolist decides whether to invest in technological innovation at a lump-sum cost of c. The monopolist will invest in innovation if and only if the additional profits from innovation outweigh the innovation cost. However, a socially efficient investment in innovation should be made if and only if the total social gain, which is the sum of the monopolist's profit and the consumer surplus of both types of consumers, exceeds the innovation cost.

We use the classical sales case as the benchmark since without innovation the game reverts to that. First we compute the social gain and the monopolist's profit in the classical sales case. The social gain from transactions in the durable goods market without innovation is [Mathematical Expression Omitted] when sales are made to type L consumers only in the second period. The monopolist makes total profits of [Mathematical Expression Omitted], leaving type H consumers a surplus of [Mathematical Expression Omitted]. Hence social efficiency dictates that an investment is to be made if and only if the total social gain after innovation exceeds [Mathematical Expression Omitted], while the monopolist will invest if and only if the monopolist's profit after innovation exceeds [Mathematical Expression Omitted].

Denoting the new social gain as W and the new monopolist's profit as [Pi], we can characterize the condition for overinvestment and underinvestment as follows. There is an overinvestment in innovation if [Mathematical Expression Omitted] and [Mathematical Expression Omitted], and at least one of the two inequalities holds strictly. Similarly there is an underinvestment if [Mathematical Expression Omitted] and [Mathematical Expression Omitted] and at least one of the two inequalities holds strictly.

We now present our main result on the choice of economic obsolescence under conditions on the parameters that correspond to those of the equilibrium characterization in Proposition 1.

Proposition 2

The optimal choices of economic obsolescence by the monopolist are:

1. If [Mathematical Expression Omitted], an underinvestment takes place for the innovation cost satisfying [Mathematical Expression Omitted].

2. If [Mathematical Expression Omitted], an underinvestment takes place for the innovation cost satisfying [Mathematical Expression Omitted].

3. If [Mathematical Expression Omitted], the monopolist invests in the innovation if and only if the social gain is bigger than the cost.

Proof

Notice that the classification in this Proposition exactly matches that of Proposition 1; in Cases 1 and 2 the monopolist makes the same investment decision. We compute the social gain in each case by adding up the

total utility from durable goods consumption. We also compute the monopolist's profit using the equilibrium price and sales sequence.

Case 1: [Mathematical Expression Omitted], [Mathematical Expression Omitted];

Case 2: [Mathematical Expression Omitted], [Mathematical Expression Omitted];

Case 3: [Mathematical Expression Omitted], [Mathematical Expression Omitted].

Since both the social gain and the monopolist's profit are exactly the same in Case 1 and Case 2, an underinvestment follows when we substitute W and [Pi] in the inequalities above defining the underinvestment. In Case 3, the total social gain and the monopolist's profit increase by the same amount, [Mathematical Expression Omitted]. It follows that there is no discrepancy between the monopolist's interest and social welfare in the investment decision. We omit further details as they are straightforward.

The conditions on the innovation cost in Proposition 2 can be alternatively explained using the change in the total consumer surplus due to innovation. Notice that the social gain from transactions in the durable goods market consists of the monopolist's profit and the total consumer surplus. For consumer surplus, we can express the condition as follows: if total consumer surplus shrinks due to innovation, then an overinvestment may occur. If total consumer surplus increases, then an underinvestment may occur. It is clear that the choice of economic obsolescence crucially depends on the interaction of the intra-type price discrimination and the inter-type price discrimination since the consumer surplus at the equilibrium outcome depends on this interaction.

In Case 3, intra-type price discrimination and inter-type price discrimination uncouple in the sense that the new product can be sold to type H with no reference to the price path of the old product. The old product price path follows the one under a standard durable goods monopoly without technological innovation. Therefore there is no reallocation of surplus between the monopolist and the two types of consumers except that there is a gain from the new product sold to type H consumers in the second period. Since the whole gain accrues to the monopolist, the monopolist invests only when it is socially optimal.

In Case 1 and Case 2 the two price discrimination schemes are linked through the new product price since type L consumers are offered the new product in the second period. Since Assumption 2 implies a wider gap between the two types of consumers' utilities for the new product than for the old product, type H consumers are allowed a bigger consumer surplus under this circumstance. Indeed an inspection of the range of the innovation cost that allows underinvestment confirms that the cases apply exactly when the innovation cost falls in the region between [Mathematical Expression Omitted] and [Mathematical Expression Omitted], which has length of [Mathematical Expression Omitted]. Since the monopolist has to allow a bigger consumer surplus in these cases, he may be reluctant to invest in the innovation in the first period.

Proposition 2 implies that the monopolist may never choose to overinvest in the innovation which reduces economic durability. This result is very different from the standard result in the planned obsolescence literature such as Bulow [1986], Choi [1994], and Waldman [1993] since they all predict overinvestment in the durability reducing technology.(4)

V. CONCLUSION

This paper analyzes the impact of technological innovation on the durable goods monopoly market equilibrium. Technological innovation which improves the quality of a durable good is characterized as

reducing durability by making the economic life shorter. We construct a simple two period durable goods monopoly model that yields a variety of equilibrium price sequences and sales patterns.

Contrary to the conventional wisdom that reduced durability alleviates the time inconsistency problem of the monopolist, there may arise an additional issue of discriminating between consumers with different purchase histories as well as different valuations. The equilibrium of the game depends on the relative numbers of consumers with different valuations and on the benefit of the innovation to consumers. For instance an innovation that improves the valuation of lower-end consumers more than of high-end ones enables the monopolist to price discriminate using an upgrade policy, which recently seems to have been a salient feature in the software industry.

The choice of economic obsolescence when there is a cost of innovation depends on the allocation of consumer surplus subsequent to the innovation. In particular the monopolist may make inefficient investment decisions to avoid weakening his market power due to the difficulty of price discrimination.

APPENDIX

Proof of Proposition 1

To facilitate the understanding of the proof, the play of the game [Gamma] is illustrated by the extensive form in Figure 1. In the figure, the branch with [q.sub.t] = 1 corresponds to the game in which consumers of type H purchase in period t while [q.sub.t] = [Mu] or [q.sub.t] = 1 + [Mu] corresponds to those in which consumers of type L or both types L and H purchase either product in period t. In the extensive form there are 16 possible outcomes of the game which we identify with terminal nodes numbered from 1 through 16.

The proof is done by comparing the payoffs from plays corresponding to the different nodes in the figure. We first prune out some terminal nodes by proving that they cannot constitute the equilibrium path. Subsequently we prove that the strategy profiles characterized in the proposition constitute the equilibrium by comparing the payoffs of players at the corresponding terminal nodes under various conditions. We use the notations [[Gamma].sub.0], [[Gamma].sub.[Mu]], [[Gamma].sub.1], and [[Gamma].sub.1+[Mu]] for subgames after the sales history of [q.sub.1] = 0, [Mu], 1, and (1 + [Mu]) respectively.

As a preliminary step, notice that at each node the profit maximizing monopolist chooses a price so that the consumers' incentive conditions are met with equality.

Any terminal nodes with no sales in the second period cannot be an equilibrium since the monopolist can earn a bigger profit by selling to any type at a small positive price. Also, any terminal nodes that belong to subgame [[Gamma].sub.[Mu]] cannot be a candidate; if the equilibrium dictates that type L consumers purchase in the first period, type H consumers can also purchase without violating the incentive constraint and yet get a higher utility. These two observations enable us to rule out terminal nodes 1, 5, 6, 7, 8, 9, and 13 from consideration.

The fact that [Mathematical Expression Omitted] which follows from Assumption 1 and Assumption 2, further removes terminal node 2 since the monopolist would make the biggest profit by selling only to type H in the subgame [[Gamma].sub.0]. In subgame [[Gamma].sub.1], the terminal node 10 can be pruned since if the price for type L consumers in the second period is higher than [Mathematical Expression Omitted], the monopolist can give a discount to type H consumers using the upgrade policy and get a bigger profit. Finally, Assumption 2 implies that terminal nodes 14 and 16 in subgame [[Gamma].sub.1+[Mu]] cannot constitute an equilibrium.

At node 4 it is necessary that the first period price is set high enough that no consumers are willing to buy the old product. In the second period, the monopolist may sell the new product to both types or the new product to type H and the old product to type L. The first choice does not yield a higher profit due to Assumptions 1 and 2 which together imply [Mathematical Expression Omitted]. Moreover selling the new product to type H and the old product to type L yields only [Mathematical Expression Omitted] since, to induce type H to buy the new product, they can be charged only [Mathematical Expression Omitted]. It is easy to see that the profit from this strategy is dominated by that from node 3.

We are now left with terminal nodes 3, 11, 12, and 15. We can further remove all nodes but 12 by comparing the payoffs from consistent play.

To reach node 3, the second period price is set as [Mathematical Expression Omitted] since there are no sales in the first period. The monopolist must charge a first period price higher than [Mathematical Expression Omitted] to avoid sales. This play yields the monopolist a total profit of [Mathematical Expression Omitted] and neither types of consumers any consumer surplus.

Node 11 is played if [q.sub.1] = [q.sub.2] = 1, that is, only type H consumers purchase in both periods. In the second period, type H consumers are willing to pay up to [Mathematical Expression Omitted] if they have an old product. Hence the monopolist charges [Mathematical Expression Omitted] for an upgrade purchase and [Mathematical Expression Omitted] for a new purchase. In the first period, the price is set equal to [Mathematical Expression Omitted] so that type H consumers are indifferent between a purchase, a future purchase, and no purchase. The monopolist's total profit is computed as [Mathematical Expression Omitted].

There are three ways to reach node 12: firstly, type L buys the new product at the new price and type H buys the new product at the upgrade price; secondly both types buy the new product at the same new purchase price in the second period; and thirdly type L buys the old product and type H buys the new product at the upgrade price.

The first case takes place if [Mathematical Expression Omitted] so that type H consumers prefer to buy the new product at the upgrade price [Mathematical Expression Omitted] rather than the new purchase price [Mathematical Expression Omitted]. The first period incentive constraint must be satisfied for type H consumers: [Mathematical Expression Omitted] and thus [Mathematical Expression Omitted]. This yields a total profit of [Mathematical Expression Omitted]. Comparing the payoffs of the players, we know that the first case and the second case are identical except for the price sequence.

If [Mathematical Expression Omitted], then the upgrade policy of charging [Mathematical Expression Omitted] is not effective if the new product is offered at the new purchase price of [Mathematical Expression Omitted]; type H consumers prefer to buy the new product at the new purchase price. In the second case the monopolist charges the same price [Mathematical Expression Omitted] for type L and type H to avoid this outcome. In the first period, the incentive constraint must be satisfied for type H consumers: [Mathematical Expression Omitted] from which [Mathematical Expression Omitted] follows. The monopolist's total profit is [Mathematical Expression Omitted].

In the third case the monopolist avoids the difficulty of price discrimination by selling the old product to type L at a price of [Mathematical Expression Omitted] while the upgrade price offered in the second period is the same as before, [Mathematical Expression Omitted]. In this case the first period incentive constraint for type H is written as [Mathematical Expression Omitted]. It remains to fix [Mathematical Expression Omitted] and [p.sub.1] so that this incentive constraint is met. If [Mathematical Expression Omitted], the right hand side of the incentive condition is [Mathematical Expression Omitted] so that type

H consumers do not get better off by buying the new product in the second period at the new purchase price than by buying the old product at [Mathematical Expression Omitted]. Given [Mathematical Expression Omitted] and [Mathematical Expression Omitted], the incentive condition is satisfied for [Mathematical Expression Omitted] and type H consumers are better off buying the old product in the first period and upgrading to the new product in the second period as desired. The total profit is [Mathematical Expression Omitted].

Node 15 is reached if type H consumers buy in both periods and type L consumers buy only in the first period. In the second period, the monopolist charges [Mathematical Expression Omitted] and [Mathematical Expression Omitted]. The first period price must make type L consumers break even: [Mathematical Expression Omitted]. Thus [Mathematical Expression Omitted] for which the incentive constraint for type H is also met. The price sequence and the corresponding purchase decisions yield the monopolist a total profit of [Mathematical Expression Omitted].

It is easy to see that node 3 is dominated by any case of node 12 and thus can be deleted from consideration. Node 15 is dominated by one of the three eases of node 12. Notice that the third case of node 12 always dominates node 15 since [Mathematical Expression Omitted] which in turn follows from [Mathematical Expression Omitted] by Assumption 1. Node 15 dominates the first and second cases of node 12 only when [Mathematical Expression Omitted]. However, if this inequality holds true, the third case, which dominates node 15, is played in the subgame [[Gamma].sub.1] since [Mathematical Expression Omitted]. It follows that node 15 is always dominated by one of three cases of node 12 and cannot constitute an equilibrium.

Finally node 11 is not credible in view of the third case of node 12. Given the first period sales of the old product to type H, the monopolist can always sell the old product to type L in the second period without violating the incentive constraint in the subgame [[Gamma].sub.1]. Since type H consumers get a positive consumer surplus if they purchase the old product in the second period while they get no surplus at node 11, type H consumers will not pay the price which node 11 dictates in the first period. As a result node 11 cannot constitute an equilibrium. Which case of node 12 is selected as the equilibrium depends on the parameter values at hand.

Since all cases of node 12 have the same first period sales, the choice among the three cases of node 12 depends entirely on whether the upgrade policy price discriminates between the consumers and on the second period profit but not on the total profit.

If [Mathematical Expression Omitted], then the monopolist can sell the new product to both types using the upgrade policy. It follows that [Mathematical Expression Omitted], [Mathematical Expression Omitted], [Mathematical Expression Omitted] and consumers of type H purchase in both periods and consumers of type L purchase the new product in the second period. Since this strategy yields a profit of [Mathematical Expression Omitted], which dominates the profit from either case 2 or case 3 of node 12, it is the subgame perfect equilibrium.

If [Mathematical Expression Omitted], the upgrade policy does not induce type H to purchase the new product at the upgrade price of [Mathematical Expression Omitted] if the new product is sold at the new purchase price of [Mathematical Expression Omitted]. Hence the monopolist may offer the new product to both types at the same price of [Mathematical Expression Omitted], or offer the new product only to type H at the upgrade price of [Mathematical Expression Omitted] and the old product to type L. The choice depends on which strategy yields a higher profit.

If [Mathematical Expression Omitted], then the monopolist sells the new product to both types at the

uniform price of [Mathematical Expression Omitted]. Otherwise the monopolist price discriminates by selling different products to different types. The new product is offered to type H at the upgrade price of [Mathematical Expression Omitted] and the old product is offered to type L at the price of [Mathematical Expression Omitted].

Collecting these results, we have the equilibrium characterized in the proposition.

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1 Although we consider only the upgrade policy, it is easy to see that other pricing policies such as bundling, buyback or trade-in would enable the monopolist to achieve the same goal of discriminating repeat buyers from others. In the following we regard the upgrade policy as broadly representing these alternatives when necessary.

2 Note that if valuations vary proportionally over periods, i.e., [Mathematical Expression Omitted], k [greater than] 1, [Theta] = L, H, then Assumption 2 implies Assumption 1. Moreover Assumption 1 and Assumption 2 together imply that [Mathematical Expression Omitted].

3 We assume that the rental arrangements involve prohibitively high transaction costs.

4 The previous version of the paper had a case of overinvestment when the monopolist shelves the old product in the second period. This result follows from the fact that shelving the old product in the second period works as a commitment enabling the monopolist to gain market power under innovation.

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